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DESIGN AND OPERATION OF A
PORTABLE SOIL-BLOWING
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DESIGN AND OPERATION OF A PORTABLE SOIL-BLOWING WIND TUNNEL¹

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Lb
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INTRODUCTION

An artificial airstream, such as that produced by a wind tunnel, is a useful research tool for studying the mechanics of wind erosion, assessing abrasive damage to growing plants, and evaluating the effectiveness of wind erosion control practices. The extreme variability and unpredictability of natural winds, with attendant lack of control over variables involved, make it practically impossible to evaluate field conditions. Studies of basic wind erosion mechanics and evaluations of some control practices can be accomplished in laboratory wind tunnels; however, some field conditions cannot be duplicated in the laboratory and a portable soil-blowing wind tunnel is needed. This publication presents information on the design and performance of a portable soil-blowing wind tunnel.

Chepil³, Joy⁴, Schoenleber⁵, and Zingg⁶ have all developed portable soil-blowing wind tunnels. Each of these tunnels consisted of a blower, an engine, a transition section, some means of straightening airflow, and a means of transporting. All were blower-type tunnels with differences mainly in the size of ducts and in the amount of refinements.

Zingg⁶ stated the requirements of a portable soil-blowing tunnel as follows: (1) The wind tunnel must be capable of producing an airstream free of general rotation and of known and steady characteristics; (2) it must provide easy and positive control of a range of wind velocities and forces common to the natural wind; (3) it must be durable; (4) it must be safe to use; (5) it should have sufficient size to afford free movement and representative sampling of eroding materials over field surfaces; (6) it must have ready portability; and (7) it should be light in weight and amenable to quick and positive assemblage and dismantling.

The portable soil-blowing wind tunnel constructed at the U.S. Big Spring Field Station meets all these requirements plus the following improvements on Zingg's design: (1) The tunnel can be rotated to any angle between 0 and 90 degrees and (2) a hoisting mechanism permits lifting and moving of the entire tunnel, thereby reducing the number of men required for its operation.

DESIGN FACTORS

Factors considered in the design of this soil-blowing tunnel are: (1) Movable in the field by either truck or tractor; (2) wind velocities up to 40 m.p.h. in the duct; (3) duct length from 24 to 48 feet; (4) tunnel rotation from 0 to 90 degrees; (5) duct tall enough to place on sorghum stubble; and (6) flow patterns comparable to natural winds.

¹ Contribution from the Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Texas Agricultural Experiment Station.

² Soil Scientist, USDA, Big Spring, Tex., and Research Soil Scientist, USDA, Watkinsville, Ga., formerly located at Big Spring, Tex.

³ Soil Research Laboratory. Report of investigations. Swift Current, Saskatchewan, Canada, 1943.

⁴ Joy, E. C. Annual report on wind erosion investigations in South Dakota. S. Dak. Agr. Expt. Sta. and USDA, Soil Conserv. Serv., (unpublished) 1941.

⁵ Department of Agricultural Engineering. Progress report of investigations on wind maker studies. Kans. State Univ. and Div. of Res., Soil Conserv. Serv., Amarillo, Tex., (unpublished) 1942.

⁶ Zingg, A. W. A portable wind tunnel and dust collector developed to evaluate the erodibility of field surfaces. Agron. Jour. 43: 189-191. 1951.

DESCRIPTION OF TUNNEL

Commercial equipment was used in construction insofar as possible. The air-moving unit consists of a Joy Axivane Series 1000 Fan⁷, Model 42 1/4 - 26 1/2 BD, with a volume range of 21,500 to 63,500 c.f.m. At maximum output, power requirements are 74 hp. with a total pressure of 4.6 inches of water. The fan is driven with a 207 hp. governor-controlled Waukesha gasoline engine. Side view of power unit and trailer is shown in figure 1.

The motor and fan are mounted on an 8- by 7-foot 1/2-inch plate. This plate is attached to a 42-inch-diameter, 1/2-inch-thick plate (fig. 2, A and B, and fig. 3). These two plates make up the turntable. The turntable rests on another 42-inch-diameter plate attached to a trailer. The two round plates turn on each other.

The trailer frame is 12.5 feet long (including hitch) and 42 inches wide. Dual wheels on each side of the frame make the overall width 93 inches. Top view of trailer is shown in figure 4.

The dual wheels raise and lower the trailer with hydraulic cylinders (figs. 5, 6, and 7). Hydraulic brakes are installed on the inside wheel of each dual.

The hitch is raised and lowered with a hydraulic cylinder (fig. 8). This cylinder and the cylinder on each dual wheel allow for leveling the tunnel on any terrain.

The airstream passes from the 42 1/4-inch round fan section through a 6-foot-long light-weight aluminum transition section to the 3- by 4-foot duct. In passing from the fan to the tunnel, the airstream is diffused and made uniform by a series of honeycombs, louvers, and screening. Airflow and construction details are shown in figures 9 and 10.

⁷Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U.S. Department of Agriculture.

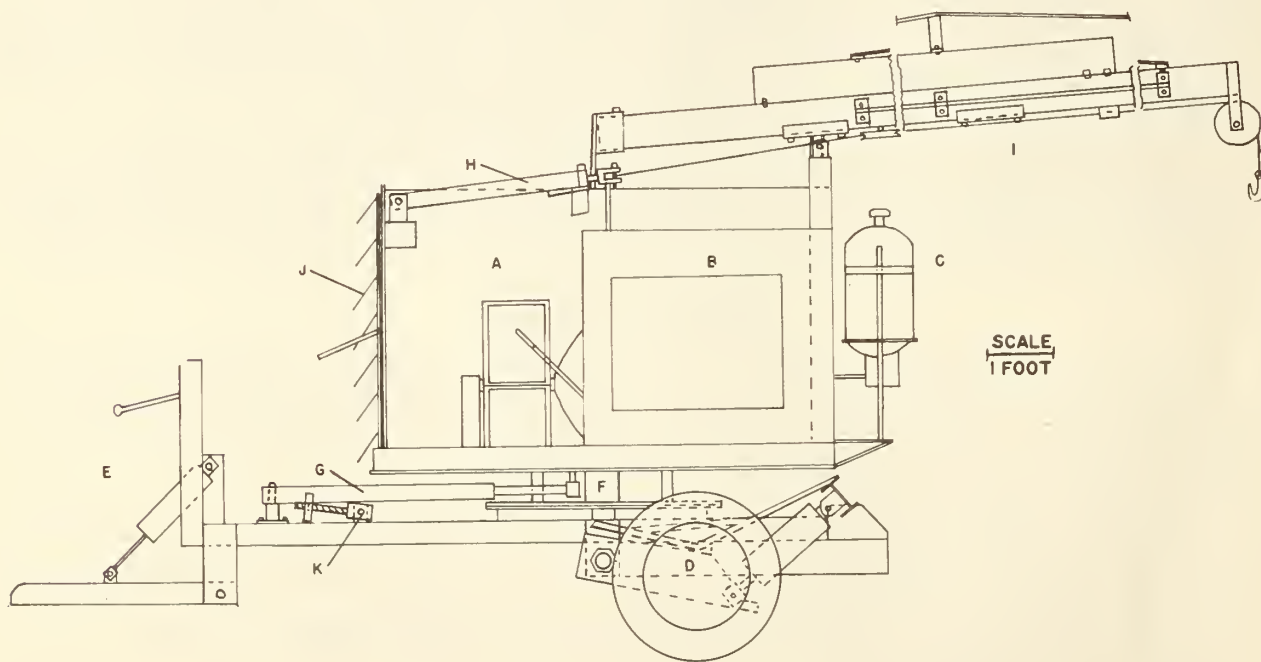


Figure 1.--Side view of power unit and trailer: A, Fan; B, engine; C, hydraulic pump and reservoir; D, dual wheels; E, hitch and control panel; F, turntable hub; G, hydraulic cylinder to rotate turntable; H, hydraulic cylinder to hoist duct; I, boom and wire rope to hoist duct; J, windspeed control louvers; K, turntable tie-down for transporting.



Figure 2.--Turntable: A, Side view; a, two 1/2- by 42-inch-diameter steel plates, bottom plate attached to trailer and top attached to turntable; b, cylinder to rotate table; c, bolts for attaching turntable gear. B, View of turntable tie-down in place.

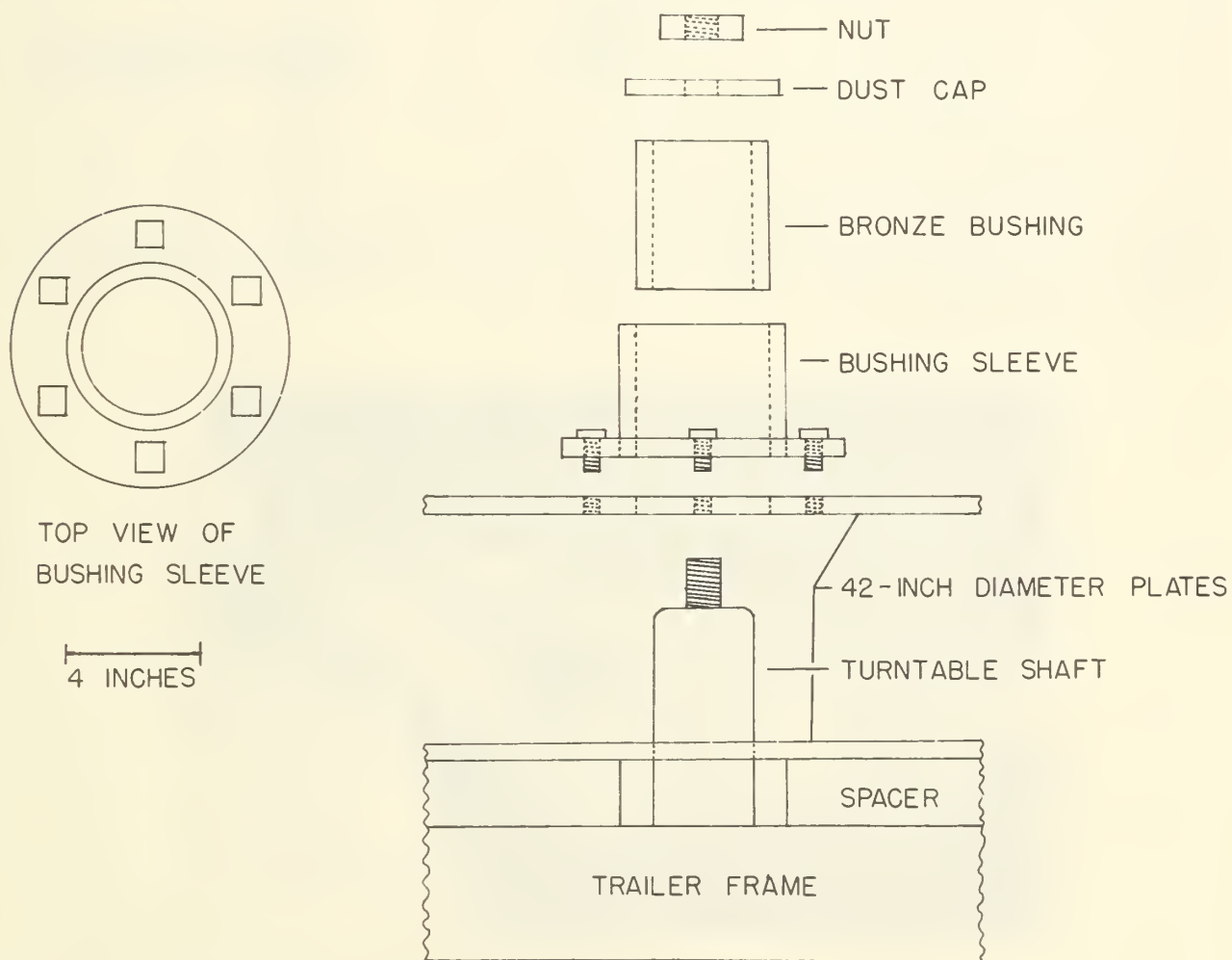


Figure 3.--Exploded view of turntable spindle assembly.

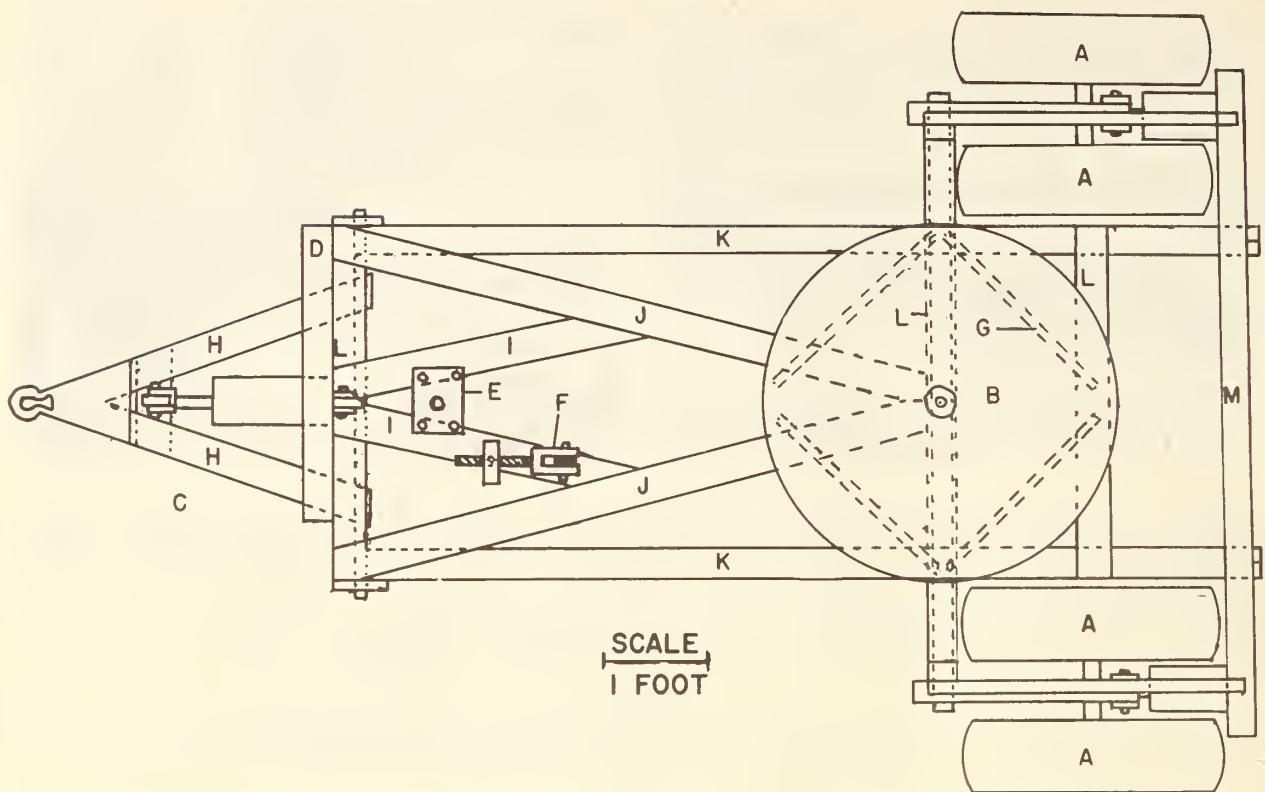


Figure 4.--Top view of trailer: A, Dual wheels; B, bottom 42-inch-diameter plate of turntable; C, hitch; D, control panel; E, mount for turntable hydraulic cylinder; F, turntable tie-down for transporting; G, turntable plate support bars--1 by 2 inches; H to L, 4- by 4-inch angle irons--39, 38, 74, 106, and 42 inches long, respectively; M, 6- by 3 1/2-inch I-beam, 79 inches long.

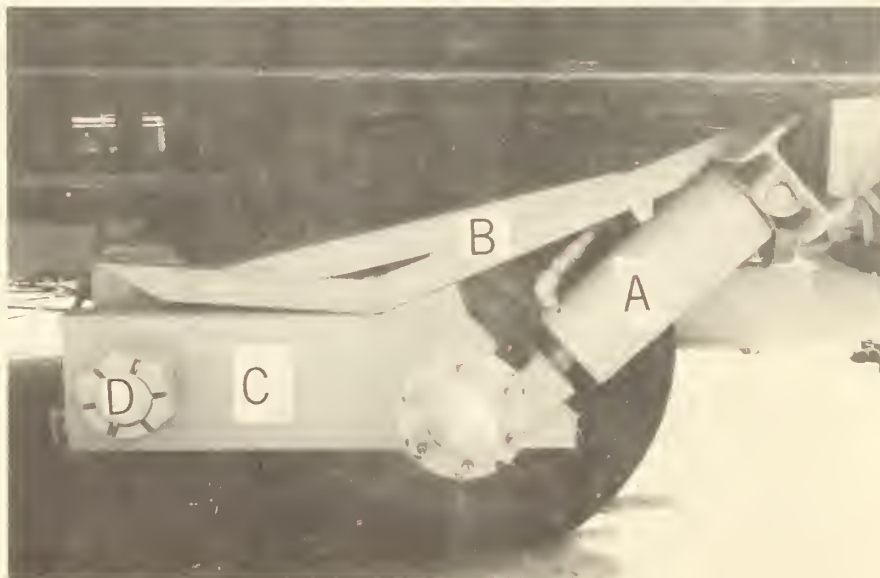


Figure 5.--Side view of drop axle with outside dual removed; A, Five-inch-bore hydraulic cylinders; B, stop on wheel for transporting and brace on cylinder mount; C, 2 1/2- by 8-inch drop axle; and D, 3-inch-diameter shaft.

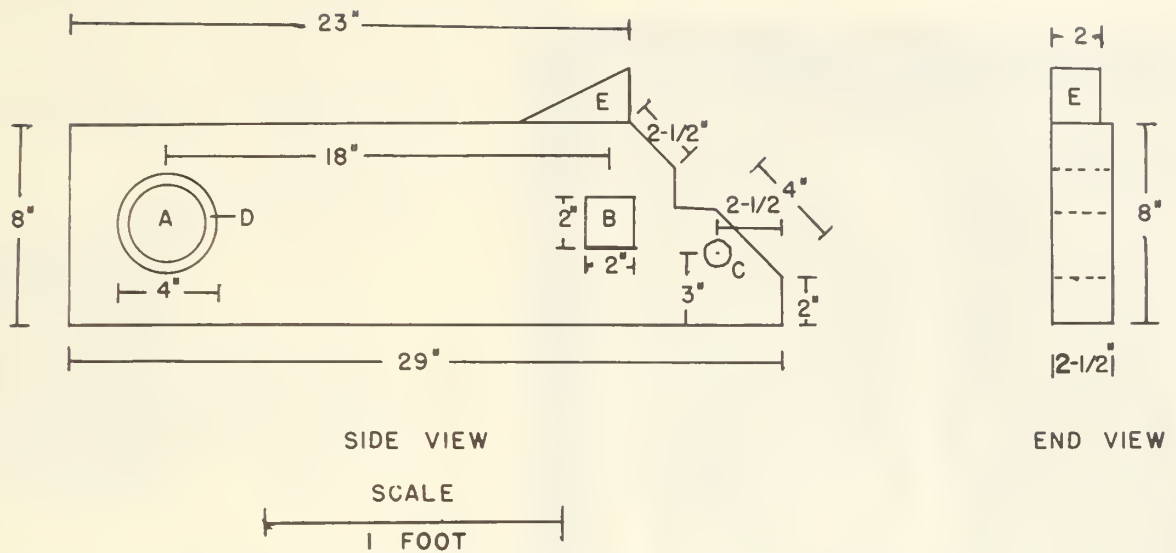


Figure 6.--Detailed view of drop axle: A, Hole for 3-inch shaft; B, hole for dual wheel axle; C, hole for hydraulic cylinder pin; D, 3-inch ID bronze bushing--press fitted; E, stop for transporting.

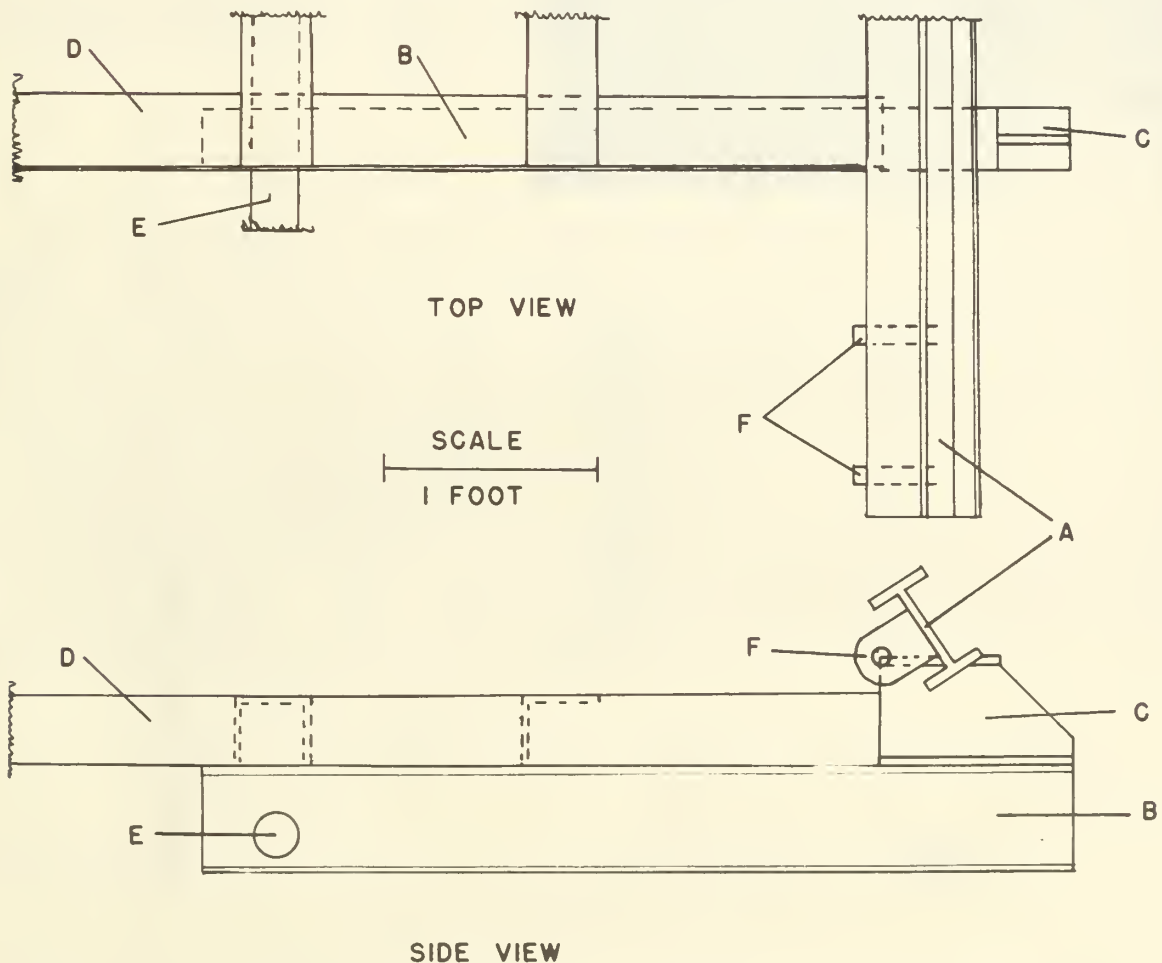


Figure 7.--View of wheel hydraulic cylinder mount: A to C, 6- by 3 1/2- by 1/4-inch I-beam--79, 49, and 11 inches long, respectively; D, trailer frame; E, 3-inch-diameter shaft; F, hydraulic cylinder mounting clevis.

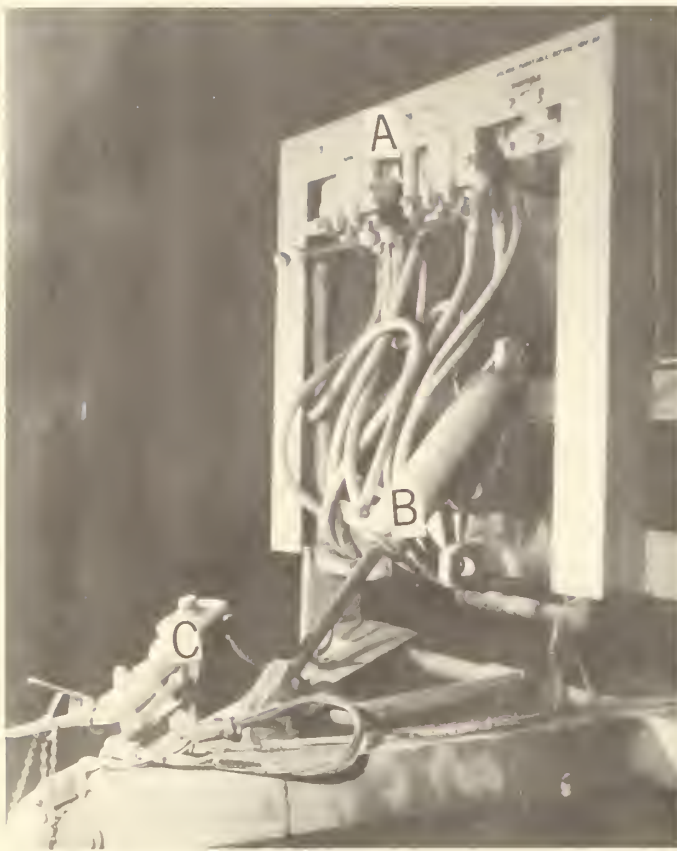


Figure 8.--View of hitch and control panel: A, hydraulic valves on control panel; B, hydraulic cylinder for raising and lowering hitch; and C, master cylinder for trailer brakes.

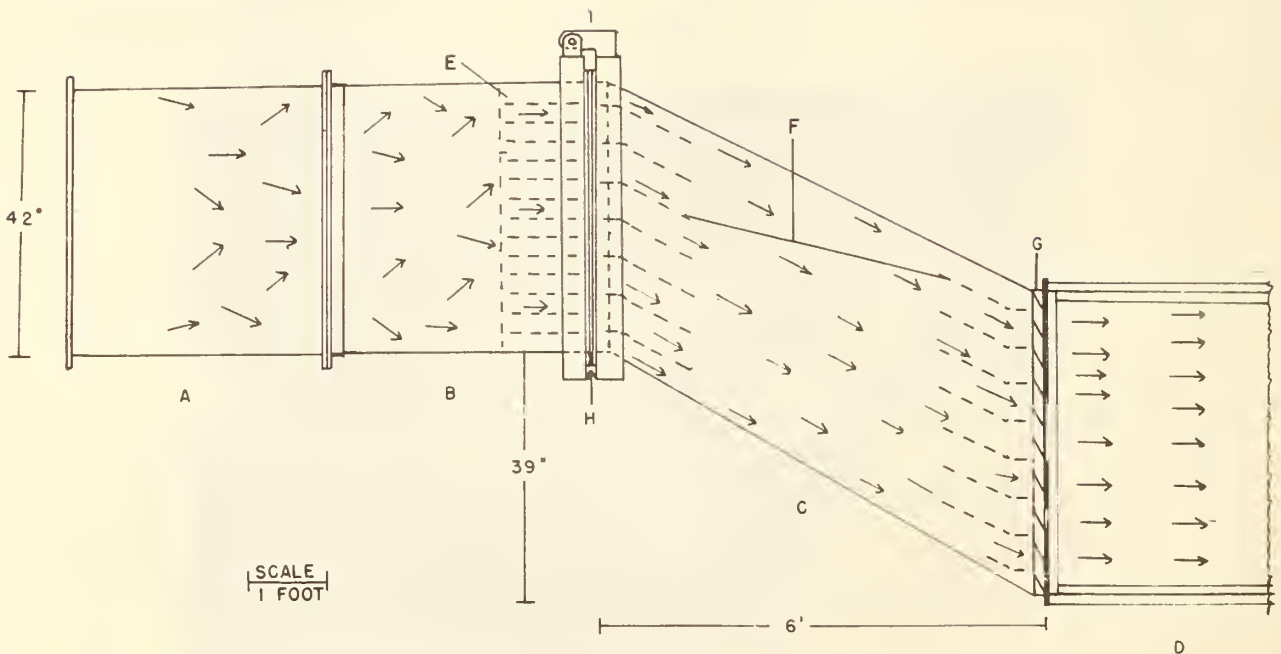


Figure 9.--Airflow from fan to duct: A, Fan; B, round aluminum section; C, transition section; D, duct; E, honeycomb--192 pieces of 3-inch downspout, 14 inches long; F, louvers; G, honeycomb material and screening (description in Materials section); H, 1/2-inch-thick foam rubber seal; I, pivot for hoisting duct.

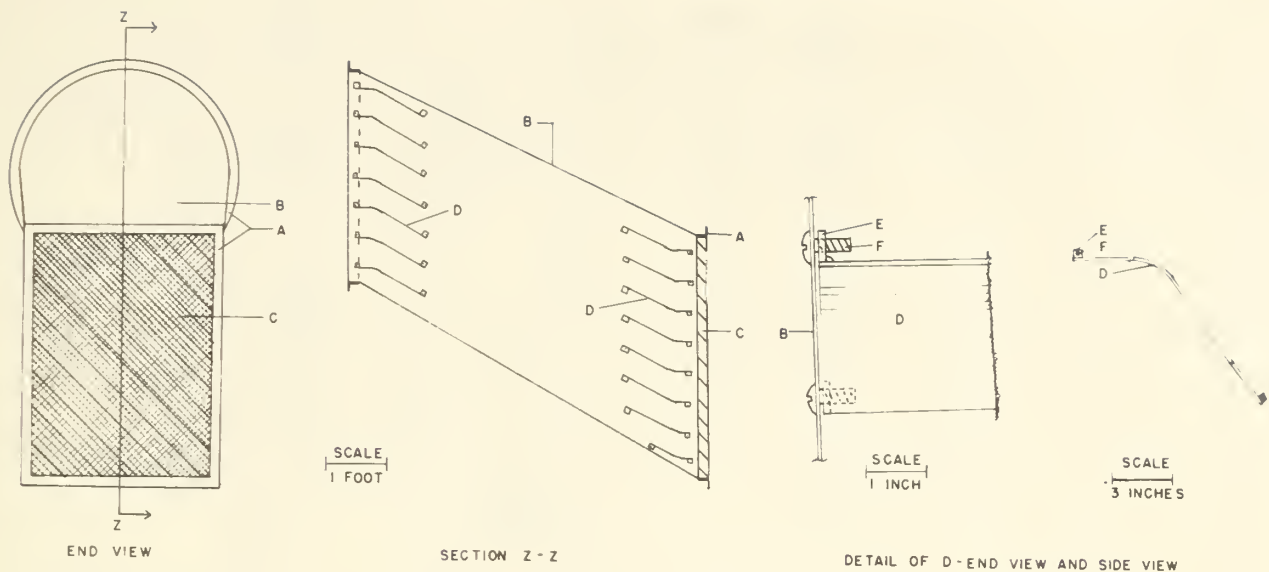


Figure 10.--Transition section and details of louver attachment: A, 2- by 2- by 1/4-inch angle iron; B, aluminum sheet (2024-T3 0.038 inch); C, honeycomb material and screening (description in Materials section); D, louver (0.125 aluminum sheet); E, 1/4-inch stovebolt nut welded to louver; F, 1/4-inch stovebolt.

The duct sections are 12 feet long by 3 feet wide by 4 feet high and are made of 2024-T3 aluminum sheets 0.038-inch thick. Three sheets form the top and side of each section. Each section is reinforced with a 1-inch by 0.25-inch-thick rivet-attached aluminum angle framework. The upper corners of each section are hinged and the entire section folds flat for ease in handling and transporting. Two sections give a duct length of 24 feet which is considered sufficient for most field research. Two other sections are available if duct lengths of 36 or 48 feet are needed. Details of duct construction are shown in figure 11.

The duct and transition section can be raised using a hydraulic cylinder, cable, and aluminum I-beam boom as shown in figures 1 and 12.

To ready the tunnel for field use the following are required: (1) Attach trailer to truck or tractor; (2) attach the aluminum transition and duct to air-delivery end of fan; (3) tow tunnel to the proper plot; (4) rotate turntable to proper angle; (5) adjust wheels and hitch until duct is in place on plot; (6) place modified Bagnold soil catchers (fig. 13); and (7) start the fan. Figure 14 shows the soil-blowing tunnel in place on a plot.

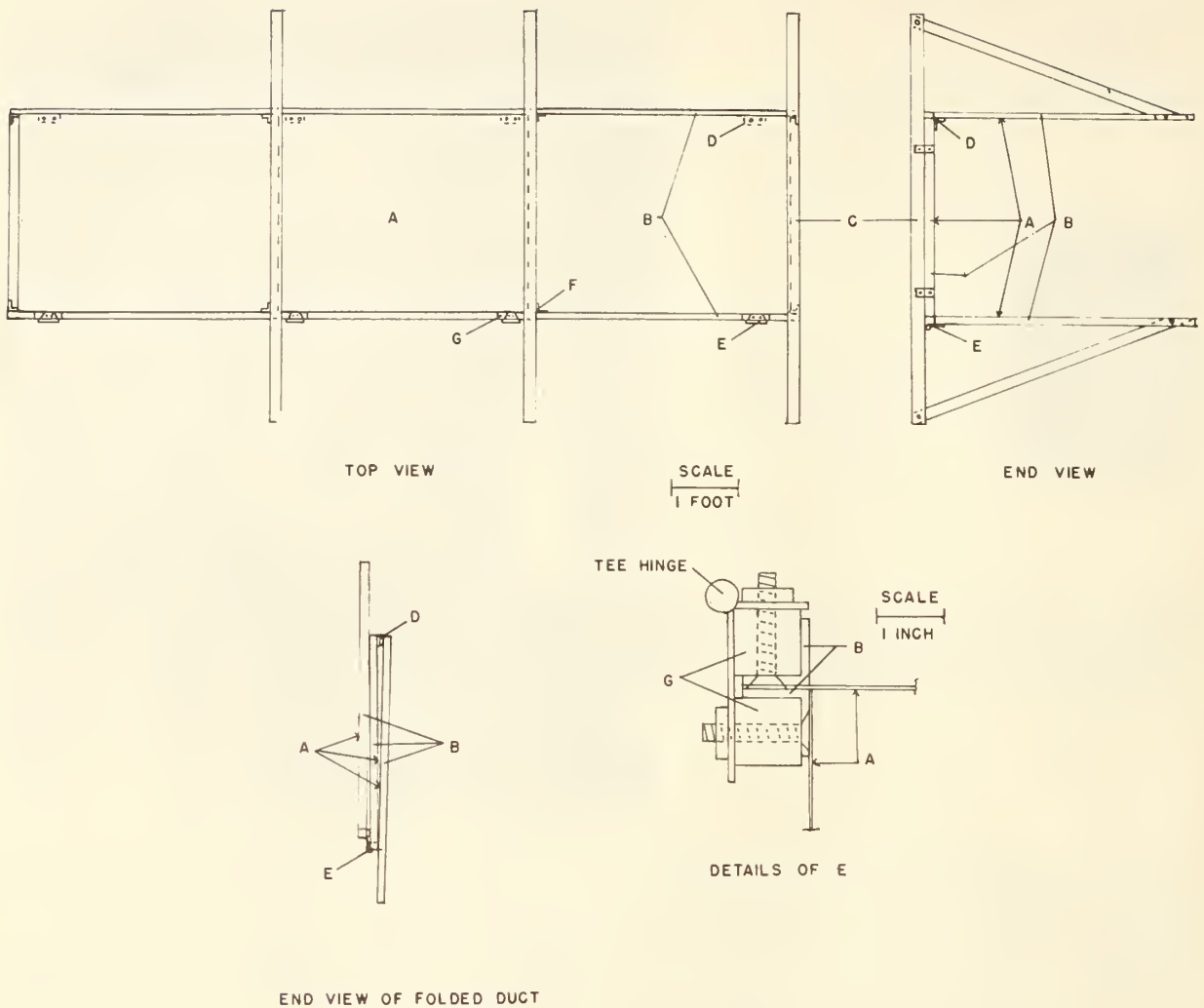


Figure 11.--Details of duct construction: A, Aluminum sheet (2024-T3 0.038 inch); B, 1- by 1- by 1/4-inch aluminum angle framing; C, 2- by 2- by 1/4-inch angle iron bracing; D, butt hinge (3 by 3 inches); E, tee hinge (6 by 1 1/2 inches); F, corner irons--riveted to framing; G, 1- by 1-inch aluminum bar.

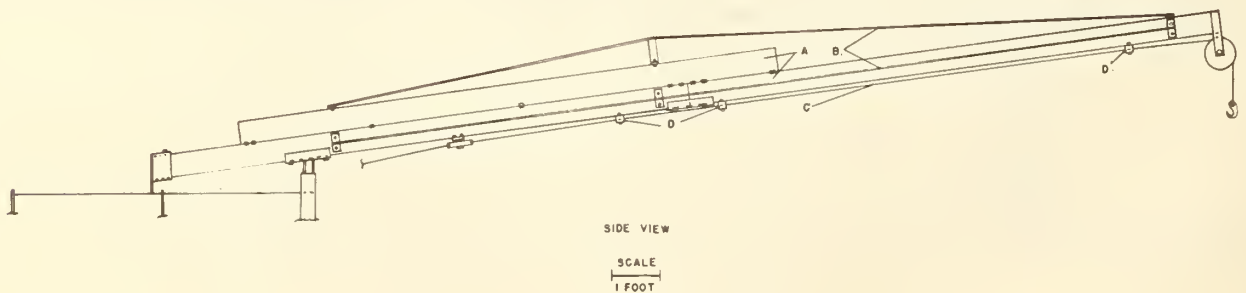


Figure 12.--Detail of hoisting boom: A, 6- by 3 3/8- by 1/4-inch aluminum I-beam; B, brace--1/2-inch rod; C, wire rope--1/4-inch; D, wire rope support.

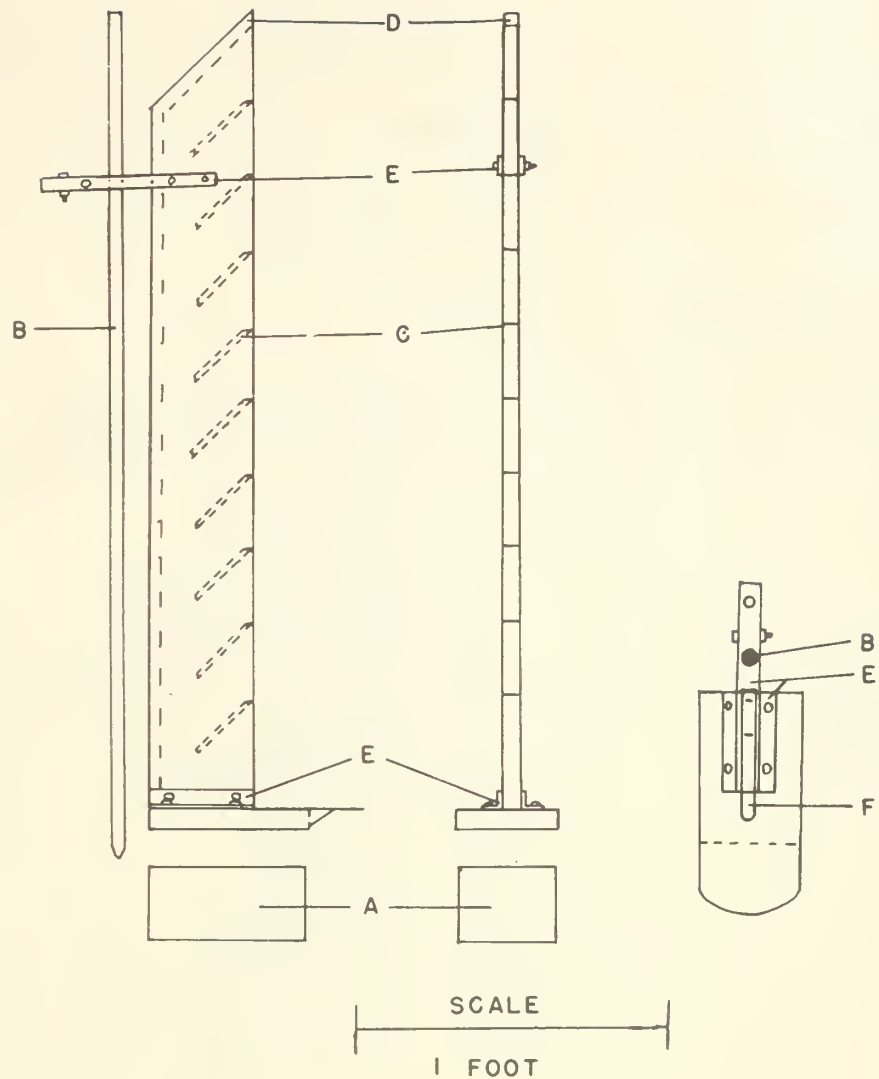


Figure 13.--Modified Bagnold soil catcher: A, Soil sample holder--heavy gage sheet metal; B, catcher support rod; C, brass deflector; D, 1/2- by 1/2-inch aluminum bar; E, 3/4- by 3/4- by 1/8-inch aluminum angle; F, slot for soil to enter sample holder.

Figure 14.--View of tunnel rotated and in place on plot (arrow indicates modified Bagnold soil catcher).



MATERIALS

Materials used in construction of trailer and duct:

Trailer

<u>Description</u>	<u>Size</u>	<u>Quantity</u>
Angle iron	4- by 4- by 3/8-in.	112 ft.
Do	1 1/2- by 1 1/2- by 1/8-in.	7 ft.
Do	3/4- by 3/4- by 1/8-in.	30 ft.
Channel	1 1/2- by 4-in.	24 ft.
I-beam	3 1/4- by 6-in.	16 ft.
Do	3- by 5-in.	1/2 ft.
Plate	6 ft. by 8 in. by 2 1/2 in.	1 each
Do	16 ft. by 4 ft. by 1/2 in.	1 each
Do	2 ft. by 4 in. by 1/2 in.	1 each
Do	1 1/2 ft. by 6 in. by 1/2 in.	1 each
Steel plates	42-in.-diameter by 1/2 in.	2 each
Flat strap	6- by 1-in.	20 ft.
Do	1 1/2- by 1/8-in.	9 ft.
Do	2- by 1/4-in.	3 ft.
Bar	2- by 2-in.	12 ft.
Do	2- by 1-in.	8 ft.
Do	1 1/2 in. round	6 ft.
Do	1 1/8 in. round	3 ft.
T-iron	4- by 2 1/2- by 1/4-in.	21 ft.
Bronze bushing	4 5/8- by 3- by 4-in.	1 each
Do	4- by 2 1/2- by 3-in.	2 each
Seamless tubing	12- by 4- by 5-in.	1 each
Do	12- by 3- by 4-in.	1 each
Do	2 1/2- by 2-in.	20 in.
Aluminum I-beam	3 3/8- by 6-in.	51 ft.
Hydraulic brake kit		1 each
Ball hitch and ball		1 each
Dual spindles with brakes, drum and hub on one side only and hub on other, each spindle rated for 5,000 lbs.		2 each
Wheels and 7.00 x 15, 8-ply tires		4 each
Turn signals		2 each
Tail light		1 each
License bracket		1 each
Amber clearance lights		2 each
Red clearance lights		2 each
Amber reflectors		2 each
Red reflectors		4 each

Duct

<u>Description</u>	<u>Size</u>	<u>Quantity</u>
Aluminum angle	1- by 1- by 1/4-in.	464 ft.
Aluminum sheets	4- by 12-ft. (2024-T3, 0.038 in.)	16 each
Butt hinges	3- by 3-in.	16 each
Tee hinges	6- by 1 1/2-in.	16 each
Corner iron braces		96 each
Turnbuckles	3/8 in.	4 each
Aluminum rivets		3 lbs.
Honeycomb material (used as insulation in airplane wings, aluminum, similar to honeybee honeycomb)	3- by 4-ft.	1 each

Hydraulic Equipment

<u>Description</u>	<u>Size</u>	<u>Quantity</u>
Cylinders	2 1/2 in. bore, 31 in. stroke	1 each
Do	3 in. bore, 18 in. stroke	1 each
Do	3 in. bore, 28 in. stroke	1 each
Do	5 in. bore, 10 in. stroke	2 each
Hydraulic pump	24 g.p.m.	1 each
Hydraulic oil filter	50 g.p.m.	1 each
Hydraulic hose	30 in. long by 1/2 in. in diameter	20 each
Do	45 in. long by 3/4 in. in diameter	2 each
Quick couplers	1 in.	2 each
Do	1/2 in.	2 each
Oil reservoir	5 to 10 gal.	1 each
Galvanized pipe	1/2 in.	50 ft.
Do	1 in.	31 ft.
Control valve with power beyond option	5 spool, four-way	1 each
Assorted pipe and brass fittings		100 each
Adaptor for pump to front crankshaft of engine		1 kit

PERFORMANCE EVALUATION

Performance evaluation was accomplished by operating the tunnel at various speeds with the duct floor covered with nonerosive gravel 1/8- to 1/4-inch in diameter. Maximum and minimum wind velocities and velocity distribution patterns were determined by using a multiple pitot tube with eight tubes 3 inches apart and a Meriam Incline Gage Manometer with ethyl alcohol as the indicating fluid. The pitot tubes were located 24 feet downwind from the airstream straighteners.

A typical distribution of airflow common to the duct is shown in figure 15. The plotted isovers are for a cross section located 24 ft. downwind with the duct floor covered with non-erosive gravel 1/8- to 1/4-inch in diameter.

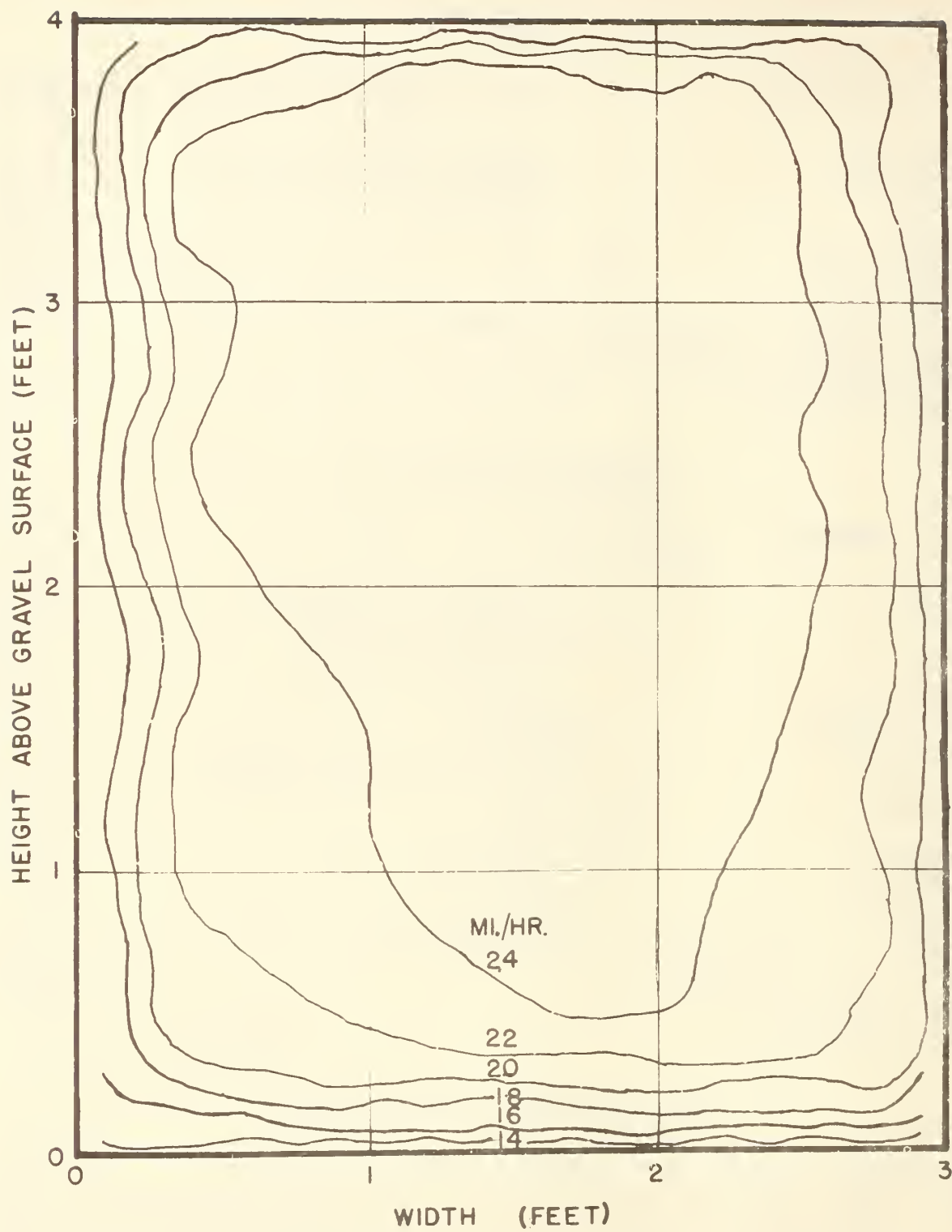


Figure 15.--Velocity distribution 24 feet downwind in duct.

The vertical profile along the centerline of the duct 24 feet downwind (fig. 16) compares favorably with those given by Zingg and Chepil.⁸

The wind velocity is controlled by louvers at the intake of the fan and through throttle and governor controls on the engine. The use of these two controls gives a velocity range of 8.0 to 39.3 m.p.h.

⁸ Zingg, A. W., and Chepil, W. S. Aerodynamics of wind erosion. Agr. Engin. 31: 279-284. 1950.



Figure 16.--Vertical profile at centerline of duct 24 feet downwind in duct.

DISCUSSION

Several problems were encountered when the turntable was incorporated into the design. The first and most important was dropping the airstream 39 inches with the transition section to get from the fan to the duct. Two sets of louvers were used to straighten the airstream--one to turn the airstream downward at the end of the fan section and the other to direct the airstream horizontally into the duct. This problem could be eliminated by mounting the turntable, power unit, and fan on a lower trailer or redesigning the trailer to lower the turntable.

The second problem was how to rotate the turntable. We used a hydraulic cylinder for a 90-degree rotation. It would be possible to use a hydraulic motor and gear arrangement and rotate the table 180 degrees. This design can be adapted to our present turntable by attaching the gear to the top 42-inch-diameter plate as shown in figure 2, A.

The third problem is counterbalancing the transition section and duct. Weights were added on the rear of the turntable. The fan and power unit could be mounted offcenter enough to balance the transition section and duct over the turntable shaft.

On plots with small soil roughness, the duct would not rest flat on the soil surface and air leaks were evident. A 1 1/2- by 1 1/2- by 1/8-inch angle iron on each edge of the duct is pushed into the ground by the weight of the duct and all leaks are stopped. This is much better than backfilling with soil, especially if the plots are exposed several times.

The soil-blowing wind tunnel has worked well on ridges, grass rows, and smooth soil surfaces. With a few additions for strength to the duct and transition section, no additional work has been necessary.

It was found that on small surface roughness, the duct itself could be raised high enough for moving by using the wheel cylinders alone.

Two men can operate the soil-blowing wind tunnel easily, and about 3 minutes are needed to move the tunnel from one exposed plot to the next.